

Hybrid Fuzzy Delphi and AHP Method for Evaluating Multi-Criteria of Factors Affecting Student Graduation

Ida Mulyadi^{1*}, Titik Khawa Abd Rahman², Muhammad Faisal³

^{1,3}Department of Informatics, Universitas Muhammadiyah Makassar, 90221, Indonesia

²Department of School of Science and Technology, Asia E University, Kuala Lumpur, 50000, Malaysia

Corresponding Author Email: idamulyadi@unismuh.ac.id

Abstract

There are many interconnected factors that affect a student's ability to graduate, such as their academic success as well as psychological, social, and institutional factors. Finding and ranking these factors is important for raising the level of higher education and lowering the number of students who drop out. This research suggests a mixed method that combines the Fuzzy Delphi Method (FDM) and the Analytic Hierarchy Process (AHP) to look at many things that affect a student's graduation. The FDM is used to sort and confirm expert views about important criteria, which makes expert judgments less subjective and uncertain. Following this, AHP is used to organize and rank the factors by comparing them pairwise. The hybrid method makes it possible to find the most important factors that affect graduation in a planned way. The results show that the most important factors are academic success, student motivation, financial stability, and institutional support. The suggested hybrid framework gives policymakers a strong tool for making decisions about policies and strategies to help students.

Keywords: Fuzzy Delphi Method; Analytic Hierarchy Process; Student Graduation; Higher Education

1. Introduction

Many people agree that graduation rates are a good way to measure how well higher education is performing. Universities are increasingly under pressure to retain their students and ensure they graduate on time. Several factors, such as academic success, socioeconomic background, psychological strength, and institutional support, were found to influence graduation in previous studies. However, ranking the criteria based on these factors is still difficult because experts' opinions are subjective and could be wrong. Some previous studies have applied hybrid Fuzzy Delphi with AHP, research that identifies and prioritizes factors influencing student satisfaction in high school [1]. Research that classifies and prioritizes criteria in the food supply chain [2]. Research assessing the main barriers to the adoption and use of solar water heaters [3]. Research ranking effective material selection criteria. Research for strategic decision-making in TVET higher education [4]. Research to design digital reading modules for students in Riau, Indonesia [5]. Research integrating Fuzzy Delphi and the Best Worst Method (BWM) to measure performance in higher education [6]. Research developing a decision-making strategy for selecting FDM-based thermoplastics produced additively for industrial applications [7]. Statistical surveys and regressions, which are common methods for decision-making, don't always reveal how fuzzy human judgment can be. Multi-Criteria Decision Making (MCDM) methods have been used by experts to address this issue [8]. The Fuzzy Delphi Method (FDM) is effective in achieving consensus among experts when there is confusion [9], while the Analytic Hierarchy Process (AHP) provides a solution for structuring criteria [10]. However, there hasn't been much research examining the use of relevant criteria



based on factors influencing student graduation using both approaches simultaneously.

This research uses FDM and AHP hybrids to identify relevant criteria and rank them based on factors influencing student graduation. This provides colleges and universities with a useful tool for decision-making.

2. Methodology

2.1 Research Framework

The stages of this research used a method consisting of:

1. Experts (academic advisors, teachers, and managers) evaluated the use of relevant criteria that have factors influencing student graduation using the Fuzzy Delphi method by examining and confirming the agreement of experts in identifying the criteria.
2. The AHP method was used after obtaining the results from Fuzzy Delphi and validated in a hierarchy and compared with each other. This model measures the Consistency Ratio (CR) to ensure accurate decisions, allowing the process to continue with the ranking of these criteria by assigning priority weights.

2.2 Data Collection

The criteria were collected from several previous research reviews, resulting in a total of 41 criteria. A team of 16 education experts from several universities with a minimum of 10 years of work experience. The collection of several factors influencing student graduation is compiled from academic factors, financial and family factors, institutional factors, social factors, and health factors found in research papers and through discussions with experts.

2.3 Input Data

The input data is taken from the results of expert assessments using 5 numbers: 5 (veryhigh), 4 (high), 3 (medium), 2 (low), and 1 (very low). Then, these assessments are converted using the Fuzzy Delphi model into 3 fuzzy values: Fuzzy High $\min(1, (x-5)/5)$, which results in a value less than or equal to 1. Fuzzy High will have a higher value when the score is higher. Fuzzy Medium $(x-5)/5$ This is the value converted according to the difference between the score and 5 (the average Likert score), divided by 5. Fuzzy Low $\max(0, 1 - (x-5)/5) \rightarrow$ This results in a value greater than or equal to 0. Fuzzy Low will have a higher value when the score is lower. The result is a score in the form of a list [low fuzzy, medium fuzzy, high fuzzy] for each score. The explanation above uses the following formula: 32

$$\begin{aligned} LF(x) &= \max\left(0, 1 - \frac{x-5}{5}\right) \\ MF(x) &= \frac{x-5}{5} \\ HF(x) &= \min\left(1, \frac{x-5}{5}\right) \end{aligned}$$

Calculate the consensus (fuzzy average)

Calculate the average of the previously calculated fuzzy values by taking the average of the three fuzzy values (low, medium, high) found in each element. Shown in this formula: 3

$$Fuzzy\ Average = \frac{1}{n} \sum_{i=1}^n F(x_{i,k})$$

Calculate of AHP

a. Pairwise Comparison Matrix for 41 Criteria

$$\begin{pmatrix} 1 & \frac{A_1}{A_2} & \frac{A_1}{A_3} & \dots & \frac{A_1}{A_{41}} \\ \frac{A_2}{A_1} & 1 & \frac{A_2}{A_3} & \dots & \frac{A_2}{A_{41}} \\ \frac{A_3}{A_1} & \frac{A_3}{A_2} & 1 & \dots & \frac{A_3}{A_{41}} \\ \dots & \dots & \dots & 1 & \dots \\ \frac{A_{41}}{A_1} & \frac{A_{41}}{A_2} & \frac{A_{41}}{A_3} & \dots & 1 \end{pmatrix}$$

b. Criteria Weight

$$Criteria\ Weight = \frac{1}{n} \sum_{j=1}^n \frac{Element\ Row_i, Column_j}{\sum_{i=1}^n Element\ Column_j}$$

c. Matrix Consistency

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI}$$

d. Alternative Evaluation

$$Alternative\ Score_j = \sum_{i=1}^{41} Criteria\ Weight_i \times Alternative\ Evaluation_{i,j}$$

3. Result and Discussion

The results and discussion section displays the input data and evaluation results from experts in Table 1. The data in Table 1 is then processed using the Fuzzy Delphi model, and the results are shown in Table 2. Table 3 displays the results of integrating the Fuzzy Delphi model with AHP.

3.1. Result

3.1.1 Data input of Expert Appraisers for Each Criterion

Table 1. Expert appraisers for each criterion

Expert	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15..	A41
Expert1	5	4	5	5	5	5	5	5	4	5	4	3	4	5	4	4
Expert2	5	4	5	5	5	5	5	5	4	5	4	3	4	3	4	3
Expert3	5	5	4	5	5	5	5	5	5	4	4	4	4	3	5	5
Expert4	5	5	5	5	4	5	4	3	4	5	4	5	3	3	5	4
Expert5	5	4	5	5	4	5	4	3	4	5	4	3	5	5	5	5
Expert7	5	5	4	4	4	5	5	5	4	5	4	4	5	4	5	4
Expert8	5	5	5	4	5	5	5	5	4	5	4	4	4	4	5	5
Expert9	5	5	5	4	5	5	5	5	4	5	4	4	4	4	5	4
Expert10	5	4	5	4	4	4	5	5	3	5	4	4	4	4	5	3
Expert11	5	5	5	4	4	4	5	5	4	5	4	4	4	4	5	5
Expert12	5	5	5	4	5	4	5	5	4	5	4	4	4	4	5	5
Expert13	5	4	5	4	5	4	4	4	5	5	5	5	4	5	5	4
Expert14	5	4	5	5	5	5	5	5	4	5	4	4	4	4	5	3
Expert15	5	5	5	5	4	4	4	4	4	4	5	5	3	4	4	5

3.1.2 Data Input Result of Model Fuzzy Delphi

Table 2. Data Input Result of Model Fuzzy Delphi

Expert	A1	A2	A3	A4	A5	A6	A7	A8..	A41
Expert1	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.266667
Expert2	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.2
Expert3	0.333333	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333
Expert4	0.333333	0.333333	0.333333	0.333333	0.266667	0.333333	0.266667	0.266667	0.266667
Expert5	0.333333	0.266667	0.333333	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333
Expert6	0.333333	0.333333	0.333333	0.333333	0.266667	0.333333	0.333333	0.333333	0.2
Expert7	0.333333	0.333333	0.266667	0.266667	0.266667	0.333333	0.333333	0.333333	0.266667
Expert8	0.333333	0.333333	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.333333
Expert9	0.333333	0.333333	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.266667
Expert10	0.333333	0.266667	0.333333	0.266667	0.266667	0.266667	0.333333	0.333333	0.2
Expert11	0.333333	0.333333	0.333333	0.266667	0.266667	0.266667	0.333333	0.333333	0.333333
Expert12	0.333333	0.333333	0.333333	0.266667	0.333333	0.266667	0.333333	0.333333	0.333333
Expert13	0.333333	0.266667	0.333333	0.266667	0.333333	0.266667	0.333333	0.266667	0.266667
Expert14	0.333333	0.266667	0.333333	0.333333	0.333333	0.333333	0.333333	0.333333	0.2
Expert15	0.333333	0.333333	0.333333	0.333333	0.266667	0.266667	0.266667	0.333333	0.333333
Expert16	0.333333	0.333333	0.266667	0.333333	0.333333	0.266667	0.333333	0.333333	0.2

3.1.3 Result of Model AHP

Based on the calculation results using the AHP method, the weight values obtained range from 0.047373 to 0.075379 for 41 criteria. However, it was agreed and recommended by experts to select criteria with a weight >0.061935 . This means only selecting relevant criteria, which are 33 out of 41 criteria. The results of the AHP model calculation are shown in Table 3.

Table 3. Result of Model AHP

Criteria	Weight	Criteria	Weight
A1	0.075379	A24	0.0625
A6	0.071511	A23	0.0625
A9	0.068384	A25	0.0625
A3	0.067709	A30	0.0625
A2	0.067395	A29	0.0625
A8	0.066858	A28	0.0625
A14	0.064494	A27	0.0625
A11	0.064184	A26	0.0625
A17	0.0625	A40	0.0625
A34	0.0625	A39	0.0625
A35	0.0625	A41	0.0625
A36	0.0625	A37	0.0625
A22	0.0625	A38	0.0625
A21	0.0625	A31	0.0625
A20	0.0625	A32	0.0625
A19	0.0625	A33	0.0625
A18	0.0625	A28	0.0625

3.2. Discussion

Table 1 presents the evaluations of 16 experts across 41 categories, with scores varying from 3 to 5. This data forms the foundation for subsequent analysis via the Fuzzy Delphi approach. The implementation of the Fuzzy Delphi model entails transforming expert evaluations into fuzzy values that signify the significance of each criterion. Table 2 presents the fuzzification outcomes, converting experts' subjective evaluations into values ranging from 0 to 1. The weights of the criterion computed via AHP in Table 3 range from 0.047373 to 0.075379. Experts concurred to choose only criteria with a weight exceeding 0.061935, resulting in the identification of 33 pertinent criteria. The Fuzzy Delphi technique enhances comprehension of expert judgments by transforming subjective evaluations into fuzzy values, whilst AHP allocates relative weights to criteria to select the most significant ones. Choosing criteria with a weight over 0.061935 eliminates the most pertinent criteria, facilitating more targeted and effective decision-making.

4. Conclusion

The study results utilizing the Fuzzy Delphi and AHP methodologies yielded criteria weights, reflecting the relative significance of the 41 criteria assessed by the experts. The fuzzification procedure utilizing Fuzzy Delphi effectively converted the experts' subjective evaluations into more nuanced fuzzy values, while AHP facilitated the prioritization of criteria based on the derived relative weights. Applying a threshold of 0.061935 eliminates 33 criteria deemed pertinent and substantial in the decision-making process. The results demonstrate that the Fuzzy Delphi and AHP approaches are proficient at prioritizing criteria and concentrating on the most significant aspects. The amalgamation of these two methodologies establishes a robust basis for more objective and systematic decision-making in identifying the criteria pertinent to the weight values employed to prioritize the criteria in this study.

5. Acknowledgement

The author wishes to convey profound appreciation to the University of Muhammadiyah Makassar for their assistance. This research could not have been conducted without the indispensable support of the University. We extend our gratitude to the reviewers for their constructive feedback and remarks, which greatly enhanced the quality of this research. We express our profound gratitude to our colleagues and partners for their invaluable talks and assistance during this project. Their involvement was essential to the effective completion of this research.

6. Reference

- [1] H. Elkadry, M. Shamsuzzaman, S. Piya, S. Haridy, H. Bashir, and M. Khadem, "A fuzzy Delphi-AHP framework for identifying and prioritizing factors affecting students' satisfaction in public high schools: Insights from the United Arab Emirates," *J. Eng. Res.*, vol. 13, no. 2, pp. 596–610, 2025.
- [2] S. Gupta, P. Chatterjee, R. Rastogi, and E. D. R. S. Gonzalez, "A Delphi fuzzy analytic hierarchy process framework for criteria classification and prioritization in food supply chains under uncertainty," *Decis. Anal. J.*, vol. 7, p. 100217, 2023.
- [3] E. B. Agyekum and V. I. Velkin, "Multi-criteria decision-making approach in assessing the key barriers to the adoption and use of SWH in West Africa—Combination of modified Delphi and Fuzzy AHP," *Int. J. Thermofluids*, vol. 23, p. 100795, 2024.
- [4] H. P. Nasution *et al.*, "Strategic decision-making in TVET higher education: Applying the fuzzy delphi technique to foster inclusive digital pedagogy in Indonesia-Malaysia," *J. Inov. Teknol. Pendidik.*, vol. 12, no. 2, pp. 231–242, 2025.
- [5] W. Syahfutra, W. M. A. Wan Daud, and N. Hafezah, "Application of Fuzzy Delphi Method in the Design of Reading Digital Modul for University Students in Riau," 2024.
- [6] S. H. H. Petrudi, H. Ghomi, and M. Mazaheriasad, "An Integrated Fuzzy Delphi and Best Worst Method (BWM) for performance measurement in higher education," *Decis. Anal. J.*, vol. 4, p. 100121, 2022.
- [7] V. K. Ojha, S. Goyal, M. Chand, and A. Kumar, "A framework for data-driven decision making in advanced manufacturing systems: Development and implementation," *Concurr. Eng.*, vol. 32, no. 1–4, pp. 58–77, 2024.
- [8] M. Retnowo, "Implementation of Multi-Criteria Decision Making (MCDM) for new student majors recommendations," *Int. J. Eng. Technol. Nat. Sci.*, vol. 4, no. 1, pp. 52–58, 2022.



- [9] Q. Xing, H. P. Tan, and S. W. Gan, “Constructing a student development model for undergraduate vocational universities in China using the Fuzzy Delphi Method and Analytic Hierarchy Process,” *PLoS One*, vol. 19, no. 3, p. e0301017, 2024.
- [10] H. Wu, “AHP model for comprehensive assessment of college students’ employability and its parameter adjustment methods,” *J. Comb. MATH. Comb. Comput*, vol. 127, pp. 2593–2616, 2025.